COMMITTEE ON
SCIENCE, SPACE AND TECHNOLOGY
CHAIRMAN FRANK LUCAS

SUBCOMMITTEE ON ENERGY

HEARING CHARTER

"Unearthing Innovation: The Future of Subsurface Science and Technology in the United States"

Wednesday, July 26, 2023
2:00 p.m.
2318 Rayburn House Office Building

Purpose
The purpose of this hearing is to explore the status of U.S. subsurface science and technology research including in the areas of fundamental scientific discovery, clean energy production and storage, waste management strategies, and next generation mining technologies. This hearing will specifically examine research and development activities carried out or supported by the U.S. Department of Energy (DOE) and will serve as a legislative hearing for bills that would authorize DOE's work in these areas as appropriate.

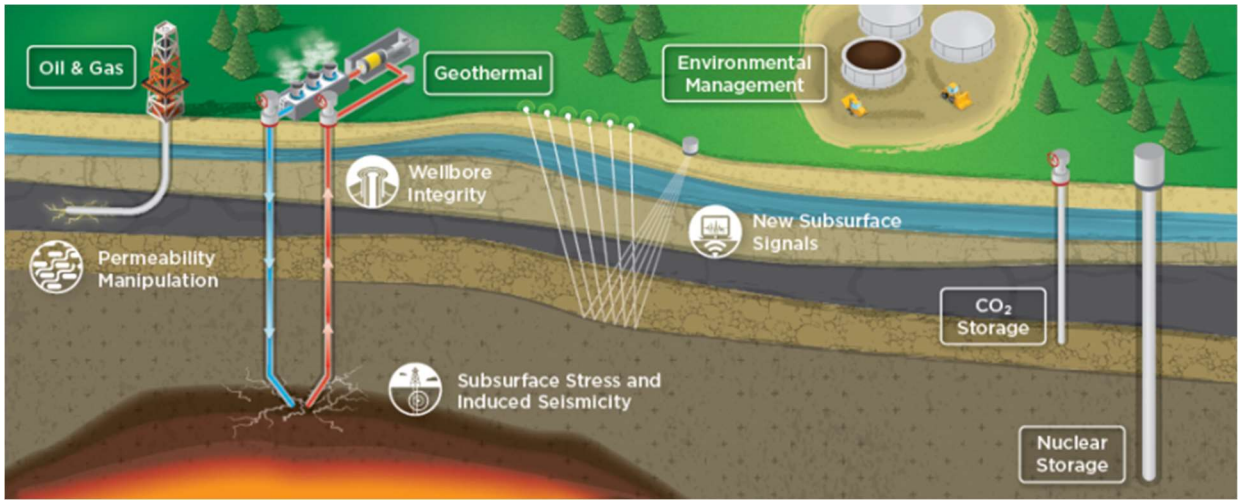
Witnesses
- **Dr. Alexandra Hakala,** Senior Fellow, Geologic and Environmental Systems, National Energy Technology Laboratory, U.S. Department of Energy
- **Mr. Ben Serrurier,** Government Affairs and Policy Manager, Fervo Energy
- **Dr. Kevin M. Rosso,** Associate Director, Physical Sciences Division, Pacific Northwest National Laboratory
- **Dr. Haruko Murakami Wainwright,** Norman C. Rasmussen Career Development Professor, Assistant Professor of Nuclear Science and Engineering, and Assistant Professor of Civil and Environmental Engineering, Massachusetts Institute of Technology
- **Ms. Allyson Book,** Chief Sustainability Officer, Baker Hughes

Overarching Questions
- What are some of the major research and development challenges associated with subsurface science and technology? What research areas need to be prioritized?
- What role do traditional subsurface energy sources play in the development of next generation ones?
- How is DOE coordinating with industry and academia to accelerate U.S innovation in subsurface science?

BACKGROUND

Subsurface energy sources are the backbone of the U.S. energy sector, responsible for meeting more than 80 percent of our nation's overall energy needs.[1] A strong understanding of subsurface systems is essential, not only for harnessing these resources, but also for expanding our clean energy portfolio, sustaining critical domestic supply chains, and securing the storage of use products like carbon dioxide and nuclear waste. Research and development into the subsurface environment and the characterization, production, and management of subsurface energy sources is critical for U.S. energy independence and national security.

For the purposes of this hearing, subsurface science and technology is a broad and multidisciplinary field of study that encompasses several important focus areas. These include fundamental research in areas like geochemistry, materials science, and computational modeling, and applied research in areas like advanced geothermal energy, carbon sequestration, mining, and waste remediation. These focus areas share a fundamental challenge: researchers in these fields are uniquely constrained by their limited ability to access, assess, and monitor the subsurface.[2]



Conceptualization of Subsurface R&D Focus Areas | U.S. Department of Energy[3]

With its network of world-leading national laboratories which steward cutting-edge research in fundamental science and diverse next generation clean energy pathways, the Department of Energy (DOE) is well positioned to lead U.S. innovation in subsurface science and technology. DOE's Subsurface Energy Innovation (SEI) Crosscut leverages expertise from across the Department through various offices, including its Office of Science, Office of Energy Efficiency and Renewable Energy (EERE), and Office of Fossil Energy and Carbon Management (FECM), among others.

To address some of the hardest challenges in this space, DOE researchers work together with industry and academic partners to support subsurface data collection, management, and standardization; create and validate complex models of geophysical and geochemical processes; develop advanced

[1] "What Is Energy?" Sources of Energy - U.S. Energy Information Administration (EIA), www.eia.gov/energyexplained/what-is-energy/sources-of-energy.php. Accessed 21 July 2023.
[2] DOE Briefing to SST Staff, 07.13.23
[3] "Subsurface Science, Technology, Engineering, and R&D Crosscut (Subter)." Energy.Gov, 9 Jan. 2014, www.energy.gov/subsurface-science-technology-engineering-and-rd-crosscut-subter.

sensor technologies durable under extreme pressures and temperatures; and facilitate technology transfer from the oil and gas industry.[4]

Fundamental Research in Subsurface Science

Through several of its core programs, DOE's Office of Science carries out significant fundamental research in subsurface science and technology.

The Basic Energy Sciences (BES) program supports advanced research in geochemistry and geophysics to improve our understanding the physical properties of the subsurface in varying environments and conditions.[5] In addition, BES supports advanced materials research to provide industry partners with better tools to operate under extreme pressures and temperatures. BES is also home to the Energy Frontier Research Centers which support a broad range of disciplines relevant to subsurface science.[6]

The Advanced Scientific Computing Research (ASCR) program supports broad subsurface science activities by maintaining advance computing capabilities and expertise and developing complex modeling techniques to predict subsurface behavior. These can be used for characterizing reservoir behavior for oil and gas activities and monitoring the movement of potentially hazardous materials underground. ASCR's leadership computing facilities are also an important resource for the subsurface science community. Models developed to replicate subsurface behavior can be incredibly complex and many researchers require supercomputers to run them effectively.[7]

The Biological and Environmental Research (BER) program supports DOE subsurface research activities through environmental system science initiatives. These initiatives focus on improving our understanding of the behavior of subsurface features within larger environmental systems, encompassing microbial, biogeochemical, hydrological, and physical processes. BER research can help subsurface scientists predict and better understand various scales of subsurface interactions. Much of this work is carried out through the Environmental Molecular Sciences Laboratory (EMSL) at Pacific Northwest National Laboratory.[8]

Enacted in 2022, the CHIPS and Science Act included a comprehensive authorization of the DOE Office of Science and specific language related to BES and BER subsurface science activities. For example, BES received updated guidance on the need for a Carbon Sequestration Research and Geologic Computational Science Initiative. This plan would leverage resources from FECM, as well as the United States Geological Survey (USGS) to make advancements in the modeling of subsurface geology for the purpose of carbon sequestration.[9]

---

[4] DOE Briefing to SST Staff 07.13.23

[5] Office of Science. "CSGB Geosciences: U.S. Doe Office of Science (SC)." CSGB Geosciences | U.S. DOE Office of Science (SC), 13 July 2023, science.osti.gov/bes/csgb/Research-Areas/Geosciences.)

[6] Office of Science. "Centers." EFRC Centers | U.S. DOE Office of Science (SC), 6 Feb. 2023, science.osti.gov/bes/efrc/Centers.

[7] Science, Office of Science. "New Geometric Model Improves Predictions of Fluid Flow in Rock." ASCR New Geometric Model Improve... | U.S. DOE Office of Science(SC), 9 Dec. 2019, science.osti.gov/ascr/Highlights/2019/ASCR-2019-06-f.

[8] EMSL Strategic Plan (pnl.gov)

[9] "Text - H.R.4346 - 117th Congress (2021-2022): Chips and Science Act." Congress.gov, Library of Congress, 9 August 2022, https://www.congress.gov/bill/117th-congress/house-bill/4346/text.

Applied Research in Subsurface Science

Geothermal Energy

Geothermal energy is an abundant and renewable energy source that generates electricity from the earth's heat. Using advanced drilling techniques, geothermal energy can provide reliable baseload power along with heat for the industrial sector. However, today geothermal power plants account for just 0.4% of the total U.S. utility scale electricity generation.[10]

Within EERE, DOE's Geothermal Technologies Office (GTO) accelerates the deployment of geothermal energy through research, development, and demonstration activities. GTO focuses on four key program areas: enhanced geothermal systems, hydrothermal resources, low temperature & coproduced resources, and data, modeling, and analysis.[11] In 2018, DOE selected Milford, Utah to be home to GTO's Frontier Observations for Research in Geothermal Energy (FORGE) program. FORGE is an enhanced geothermal system facility and dedicated laboratory, which advances research and development of drilling techniques, reservoir simulation, and flow testing efforts. In 2021, DOE awarded 17 projects to receive $46 million to collaborate with FORGE. Recently, a participant of the FORGE program, Fervo Energy, announced that over a 30-day period, it successfully attained a flow rate of 63 liters per second at high temperatures and an electric power output of 3.5 MW.[12] This is a record for a commercial pilot enhanced geothermal system site. Later this year, DOE will announce up to $44 million for 17 projects to build off FORGE's existing work.

The Energy Act of 2020 included a comprehensive reauthorization of GTO's activities including demonstration projects, milestone-based demonstration projects, research for heat pumps and direct use, expansion of FORGE, and the utilization of DOE's computing and modeling capabilities. The Infrastructure, Investment, & Jobs Act (IIJA) appropriated $84 million for enhanced geothermal systems demonstrations. DOE received full applications in June of 2023 and will announce selections by October of this year.

Fossil Energy and Carbon Management

Fossil energy sources, like natural gas, coal, and petroleum, provide reliable, low cost, baseload power. Innovation has allowed the U.S. to become a major player in the export of petroleum-based products and liquified natural gas. Thanks to advancements in horizontal drilling, 3D seismic imaging, and micro-seismic fracturing mapping, these sources account for 60% of the United States electricity generation.[13]

Through FECM, DOE supports applied research, development, demonstration, and commercialization of technologies related to fossil energy sources. DOE's National Energy Technology Laboratory (NETL) leads this cross-cutting research in areas including carbon capture, carbon transport and storage, and carbon dioxide conversion. NETL is also instrumental in the

[10] "Geothermal Explained ." Use of Geothermal Energy - U.S. Energy Information Administration (EIA), 20 Apr. 2023, www.eia.gov/energyexplained/geothermal/use-of-geothermal-energy.php.
[11] "About." Energy.Gov, 26 Jan. 2023, www.energy.gov/eere/geothermal/about.
[12] "Fervo Energy Announces Technology Breakthrough in Next-Generation Geothermal." Fervo Energy, 18 July 2023, fervoenergy.com/fervo-energy-announces-technology-breakthrough-in-next-generation-geothermal/.
[13] "Frequently Asked Questions (Faqs) - U.S. Energy Information Administration (EIA)." Frequently Asked Questions (FAQs) , 2 Mar. 2023, www.eia.gov/tools/faqs/faq.php?id=427&t=3.

development of next-generation mining technologies to support their critical materials program. This program was put in place to create new domestic sources for minerals and materials that are crucial to national security.[14] Through these efforts, NETL is developing additional methods to extract rare earth elements from coal and coal-by-products to further increase the domestic supply and to decrease dependencies internationally.

The Energy Act of 2020 enacted wide-ranging reauthorizations of DOE's FECM activities including the carbon storage validation and testing, carbon utilization, and intra-agency coordination between the FECM and the National Laboratories. In addition, it established the carbon capture technology program, which will use CCUS technology to reduce the cost and emissions from coal, natural gas, and industrial facilities through demonstration projects. The IIJA appropriated significant funds for these activities, including $2.54 billion for the Carbon Demonstration Projects program and $937 billion for Carbon Capture Large-Scale Pilot Projects.

Environmental Management

DOE's Office of Environmental Management (EM) is responsible for remediating environments impacted by the Department's nuclear activities, decommissioning contaminated facilities, and disposing of toxic waste. This important aspect of DOE's mission relies on the advancement of subsurface science and technology. Many EM sites, like DOE's Hanford Site, must have their subsurface constantly monitored. This subsurface observation requires advanced sensors and modeling software to ensure that the contaminated areas are adequately isolated.[15] In addition, in locations where nuclear waste material is being stored it is important to understand how the containers will interact with the surrounding soil on a molecular level. This helps understand the corrosion risks with the containers as well as possible safety concerns in the event of a leak into the subsurface.[16] Leading these efforts, DOE's Savannah River National Laboratory (SRNL) conducts cross-cutting research and development in areas including environmental remediation, hazardous material stabilization, processing and disposal, and nuclear processing and disposition. Innovations in these areas inform and direct future cleanup efforts across the country.[17]

While EM is not a formal participant in the DOE SEI Crosscut, its role in DOE's subsurface R&D activities is essential. In 2021, the Government Accountability Office (GAO) released a report titled, "Nuclear Waste Cleanup: DOE Needs to Better Coordinate and Prioritize Its Research and Development Efforts." In this report, GAO made several recommendations, including that DOE develop a system to collect relevant R&D information across the Department, and develop a comprehensive approach to prioritizing R&D across the EM complex.[18]

---

[14] "Critical Minerals and Materials Program." Netl.Doe.Gov, 2022, www.netl.doe.gov/resource-sustainability/minerals-and-materials/program-overview/background.

[15] United States, Department of Energy, Pacific Northwest National Laboratory. "Environmental Remediation." June 2021, https://www.pnnl.gov/sites/default/files/media/file/PNNL_EM_EnvironmentalRemediation_brochure.pdf

[16] United States, Department of Energy, Pacific Northwest National Laboratory. "Environmental Remediation." June 2021, https://www.pnnl.gov/sites/default/files/media/file/PNNL_EM_EnvironmentalRemediation_brochure.pdf

[17] United States, Department of Energy, Office of Environmental Management. "EM Strategic Vision: 2023-2033." May 2023, https://www.energy.gov/sites/default/files/2023-05/DOE%20EM%20Strategic%20Vision%202023%20%282%29.pdf

[18] U.S. Government Accountability Office. "Nuclear Waste Cleanup: Doe Needs to Better Coordinate and Prioritize Its Research and Development Efforts." Nuclear Waste Cleanup: DOE Needs to Better Coordinate and Prioritize Its Research and Development Efforts | U.S. GAO, 28 Oct. 2021, www.gao.gov/products/gao-22-104490.